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H2K

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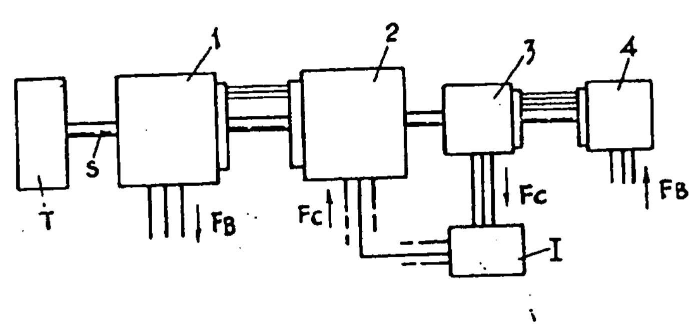
(54) **Alternating current generating equipment**

(57) An alternating current electrical power generating system has two pairs of dynamo-electric machines (1, 2, 3, 4), each machine having stator and rotor windings wound as for a wound rotor induction motor and their rotors mechanically coupled together. In each pair of machines the rotor windings are interconnected, the stator winding of one (4) of the second pair of machines being supplied with alternating current at a fixed frequency, the output of the stator winding of the other (3) of the second pair of machines being fed through an amplifier (I) to the stator winding of one (2) of the first pair of machines, and the output of the stator winding of the other (1) of the first pair of machines providing the alternating current from the system having a frequency equal to the input frequency. The number of machines can be reduced to two if slip-rings can be tolerated. The system may be powered by a turbine T driven by wind, wave or tide. Numerous modifications involving one or more induction generators and differential gearing are described.

FIG.2.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 056 183 A

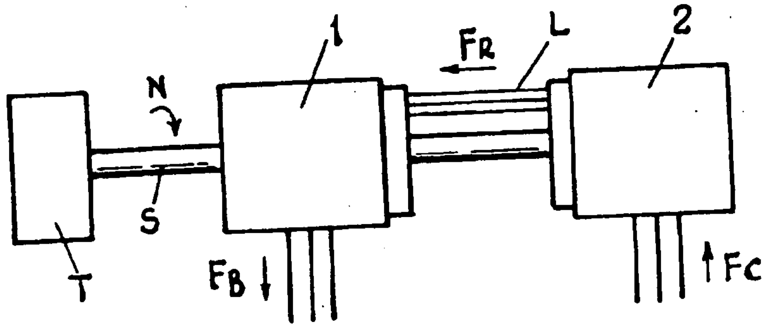


FIG.1.

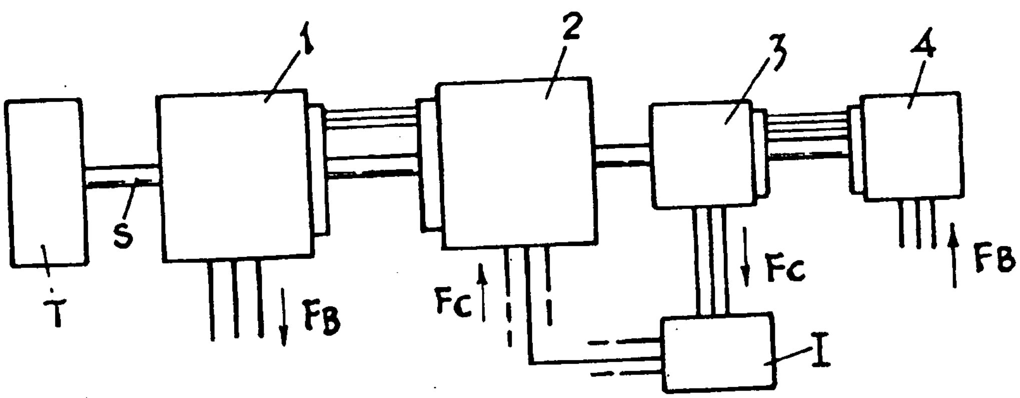


FIG.2.

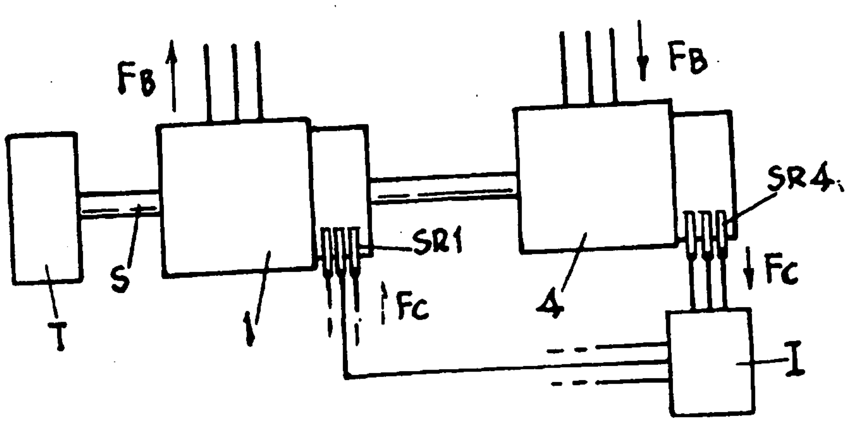


FIG.3.

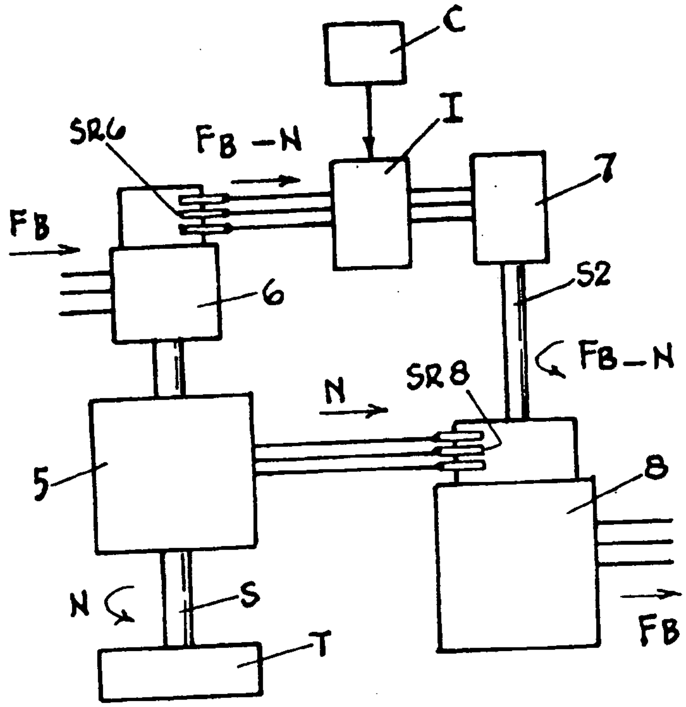


FIG.4.

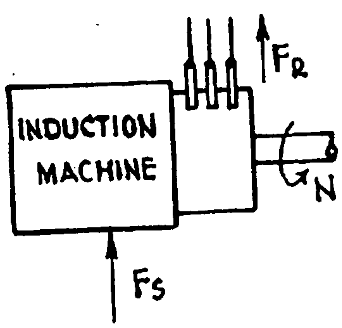


FIG.5a.

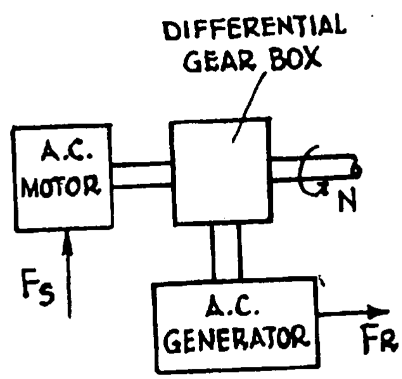


FIG.5b.

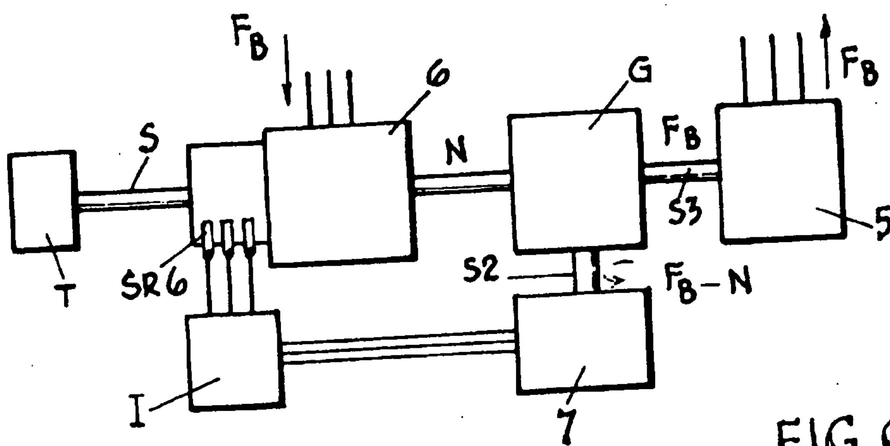


FIG.6.

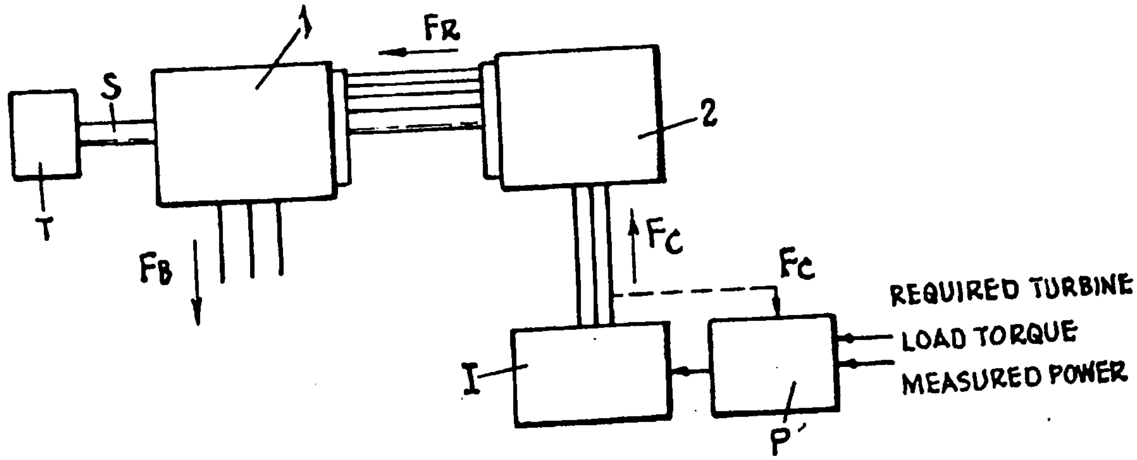


FIG.7.

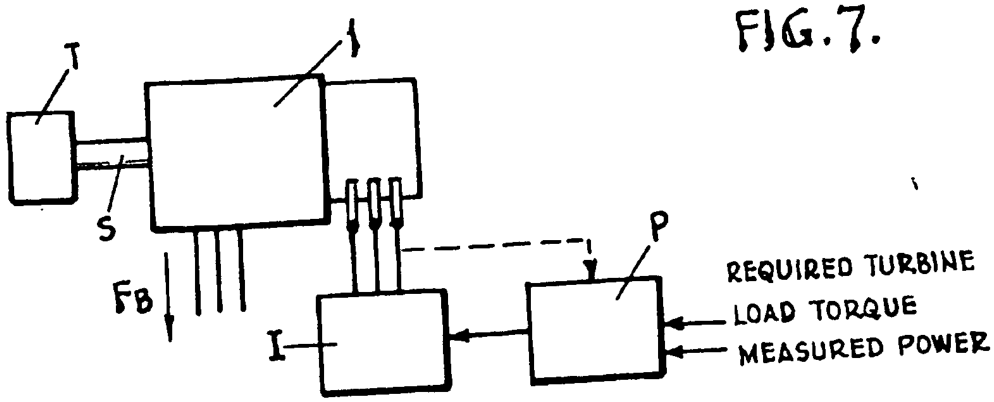
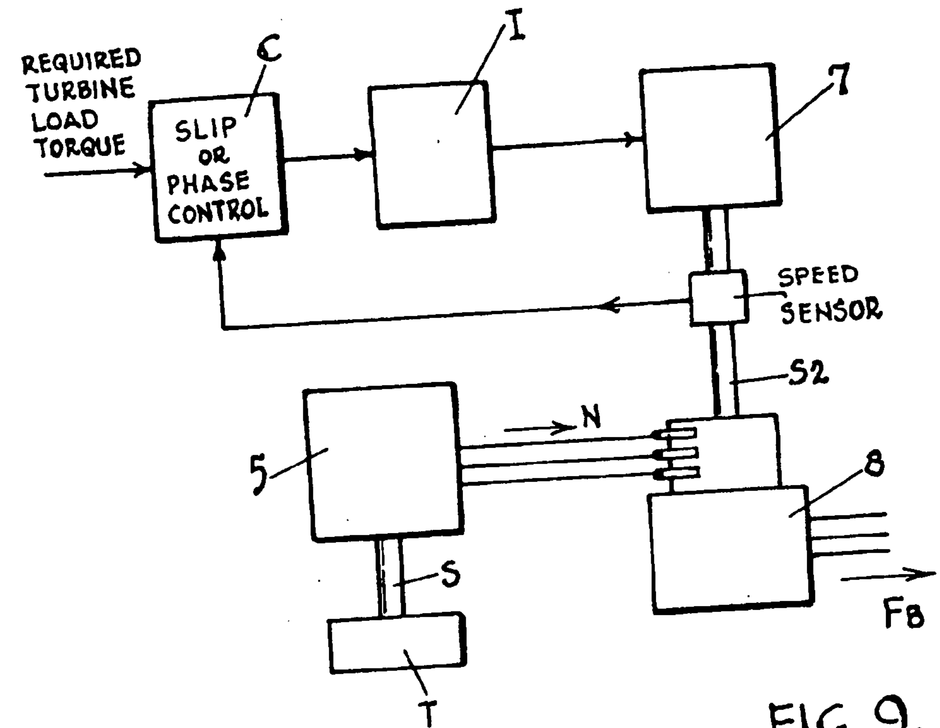


FIG.8.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LOAD
TORQUE
C
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SPEED
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FIG. 9.

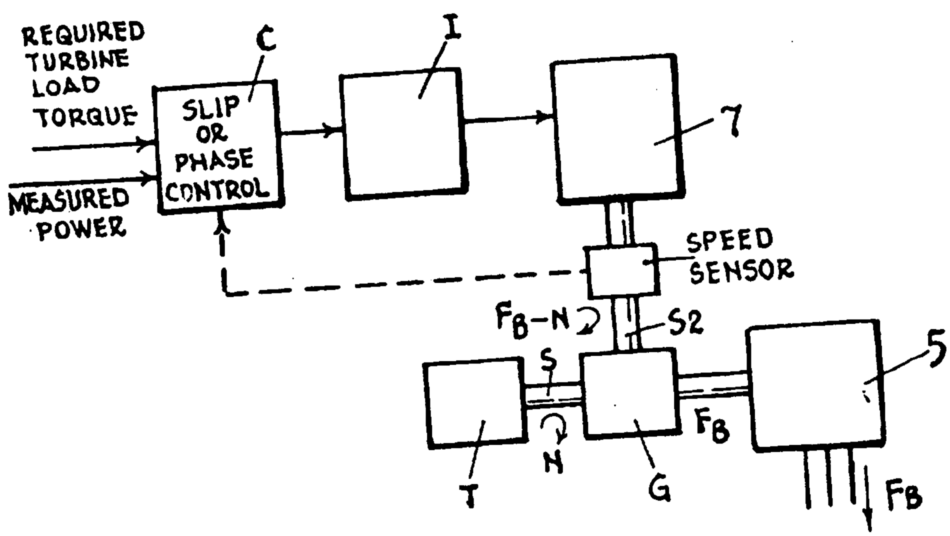
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FIG. 10.

SPECIFICATION

Power generating equipment

This invention relates to electrical power generating equipment.

On some types of power generating equipment the rotational speed of an alternating current generator may vary widely and in a random manner. Such applications include the harnessing of wave, wind and tidal power. In order to feed this power into the National Grid or to parallel a number of generators onto a common bus, the random frequency outputs from these generators must be converted into a common standard, that is 50 Hz in this country.

It has been proposed to utilise two dynamo-electric machines having stator and rotor windings wound as for a wound-rotor induction motor, with their rotors mechanically coupled together so as to be simultaneously rotated by the same prime mover, the rotor windings of the two machines being interconnected, a constant frequency excitation source being applied to the stator winding of one machine, and the stator winding of the other machine providing the output from the assembly.

Such an arrangement is illustrated diagrammatically in Figure 1, in which 1 and 2 represent two induction machines mounted on a common shaft S driven by a variable speed turbine T. The rotor windings of the two machines are interconnected by conducting links as at L. A control frequency F_c is applied to the stator winding of the machine 2, and in use an output frequency F_B will be generated by the stator winding of the machine 1. Now if N is the shaft speed and F_R the rotor current frequency $F_R = F_B - N$ and $F_C = F_R - N$. Therefore $F_C = F_B - 2N$.

It will accordingly be seen that in order to obtain a constant output frequency F_B the excitation frequency cannot be constant.

An object of the invention is to provide a power generating system of the above form modified to provide a constant output frequency.

According to one aspect of the invention an alternating current electrical power generating system incorporates a first pair of dynamo-electric machines having stator and rotor windings wound as for a wound rotor induction motor with their rotors mechanically coupled together so as to be rotated simultaneously by the same prime mover, and their rotor windings interconnected, a second pair of dynamo-electric machines having stator and rotor windings wound as for a wound-rotor induction motor with their rotor mechanically coupled to those of the first pair of machines and their rotor windings interconnected with each other, the stator winding of one of the second pair of machines being supplied with alternating current at a predetermined frequency, the output from the stator winding of the other of this second pair of machines being fed through an amplifier to the stator winding of one of the first pair of machines, and the stator winding of the other of the first pair of machines providing the alternating current output from the system.

The output frequency in such a case will be equivalent to the input frequency, which can be selected to provide an output frequency of the required value.

Thus if the input frequency to the stator of the first of the second pair of machines is F_B the output frequency from the stator of the associated machine will be equal to $F_B - 2N$ and a current of this frequency, after amplification, for example by means of a static inverter, is applied to the stator of the first of the first pair of machines. Now the rotor current frequency F_{R1} this first pair of machines is equivalent to $F_{B1} - N$ where F_{B1} is the output frequency from the stator of the second of the first pair of machines. But $F_B - 2N = F_{R1} - N$. Consequently $F_B - 2N = F_{B1} - 2N$ and $F_B = F_{B1}$, so that a power output with a frequency equal to the input frequency will be obtained from the system.

If slip rings can be tolerated the number of machines can be reduced to two. Thus in accordance with another aspect of the invention an alternating current power generating system incorporates two dynamo electric machines having stator and rotor windings wound as for a wound rotor induction motor with their rotors mechanically coupled together so as to be rotated simultaneously by the same prime mover, the stator winding of one machine being supplied with alternating current at a predetermined frequency, an alternating current derived from the rotor winding of this machine being fed after amplfication, for example by a static inverter, to the rotor winding of the second machine, and the output from the stator winding of the second machine providing the alternating current output from the system, which can be shown to have a frequency equal to the input frequency as in the arrangement previously described.

Where a static inverter is used for amplification purposes it will be seen that it is fed from a constant frequency, constant voltage supply and can therefore be of a relatively simple form, whereas arrangements in which a static inverter is used directly to convert a variable frequency variable voltage, as from a variable speed generator, directly to a fixed voltage, fixed frequency output need to be somewhat complicated and are difficult to construct satisfactorily.

Various modifications are possible as will be apparent from the following description, in which a number of different embodiments of the invention will be described by way of example with reference to the accompanying drawings.

Thus Figure 2 illustrates an arrangement in accordance with the invention having two pairs of induction machines, with their rotors all mounted on a common shaft S driven by a variable speed turbine T. The rotor windings of the machines 1, 2 are interconnected as are the rotor windings of the machines 3, 4. The stator winding of the machine 4 is supplied with alternating current at a predetermined frequency F_B, and the output from

the stator of the associated machine 3 is fed to a static inverter I which amplifies the power level and feeds it to the stator of the machine 2. The stator of the machine 1 will then generate an alternating current having the same frequency F_B as the input frequency to the system as above described.

A modified arrangement utilising two induction machines 1, 4 only, having their rotors mounted on a common shaft S, is illustrated in Figure 3. In this arrangement the stator of the machine 4 is supplied with alternating current of frequency F_B. The output from the rotor winding of this machine is fed via a slip-ring system SR4 to a static inverter I which amplifies the power level and feeds it to the rotor winding of the machine 1 via a further system of slip-rings SR1. The stator winding of the machine 1 will then generate an alternating current having the same frequency F_b as the input frequency to the system.

In the arrangements above described the power output from the inverter is proportional to $F_B - N$ for constant generator torque. Thus at full generator output the inverter output would be a minimum and would increase as the generator speed decreased. If, as is likely, the turbine torque also reduces with reducing speed the maximum output from the inverter may never be required, but it will still need to be designed for maximum voltage, and maximum current conditions.

Another embodiment of the invention is illustrated in Figure 4. In this embodiment the rotors of a main generator 5 and a smaller induction machine 6 are mounted on a common shaft S driven by a variable speed turbine T The stator of the excitation machine 6 is supplied with alternating current having a desired frequency F_B. An output current of frequency $F_B - N$ is taken from the rotor winding of the excitation machine 6 via a system of slip rings SR6, and is fed to a static inverter I, which amplifies the power level and feeds it to the stator winding of a synchronous or induction motor 7 having its rotor mounted on the same shaft S2 as an output induction machine 8. The stator of the main generator 5 is connected by a slip-ring system SR8 to the rotor winding of the output machine 8. Now in use the motor 7, as it is fed by an alternating current of frequency $F_B - N$ will tend to rotate at the same speed as the rotor of the output machine 8.

Now it is known that for any 2-pole induction machine

$$\frac{\text{Stator power}}{\text{Stator frequency}} = \frac{\text{Rotor power}}{\text{Rotor frequency}} = \frac{\text{Shaft power}}{\text{Shaft speed}}$$

Thus if the shaft torque is zero there is no power transfer between the rotor and the stator. To induce the motor 7 to induce torque it is necessary to change the phase of the supply frequency to the motor if a synchronous machine is used, or to change the frequency by an amount equivalent to the motor slip if an induction motor is used. This is conveniently achieved by suitable control of the static inverter by any convenient form of control shown at C.

Now an induction machine can be represented or replaced by a differential gear box, generator and motor as illustrated in Figure 5a and 5b.

Thus on any of the systems described above an induction machine can be replaced by such a motor, generator, gear-box arrangement. For example the embodiment illustrated in Figure 4 could be modified as shown in Figure 6. In this arrangement the rotor of the machine 6 is driven by the shaft S of the turbine T which shaft also provides one input to a differential gear-box G, N being the variable rotor shaft speed. An output of frequency $F_B - N$ is taken via the slip-ring system SR6 from the rotor winding of the machine 6 and fed to the static inverter I, the output from which is fed to the stator of an induction or synchronous motor 7, the shaft S2 of which provides a second input to the differential gear box G. This shaft will have a speed equivalent to $F_B - N$, and the differential gear-box is arranged to drive its output shaft S3, and hence the rotor of the main generator 5 a speed giving an output frequency from the stator of the machine equal to the input frequency F_B.

Figure 7 represents a modification of the embodiment illustrated in Figure 2 in which the induction machines 3, 4 are omitted. In this arrangement a static inverter I, controlled by a phase controller P which regulates a required turbine load torque, supplies to the stator winding of the machine 2 an alternating current of frequency F_C, selected so that the frequency of the alternating current output from the stator of the machine has a required value F_B.

If slip-rings can be tolerated an arrangement as illustrated in Figure 8 can be used, this being a modification of the embodiment shown in Figure 3.

Similarly the embodiment shown in Figure 4 can be modified to the form illustrated in Figure 9, and that shown in Figure 6 can be modified to the form illustrated in Figure 10, the same references being used to denote the same elements in each of the figures. The latter arrangement may be particularly advantageous in view of difficulties which can be experienced with double fed induction machines, and because the output generator, that is the machine 1, is rotated at constant speed. It may be preferable for the motor 7 to be a synchronous motor rather than an induction motor as the static inverter I need not then be forced commutated, although the control arrangements may need to be more complex.

CLAIMS

1. An alternating current electrical power generating system incorporating a first pair of dynamo-electric machines having stator and rotor windings wound as for a wound rotor induction motor with their rotors mechanically coupled together so as to be rotated simultaneously by the same prime mover, and their rotor windings

interconnected, a second pair of dynamo-electric machines having stator and rotor windings wound as for a wound-rotor induction motor with their rotors mechanically coupled to those of the first pair of machines and their rotor windings interconnected with each other, the stator winding of one of the second pair of machines being supplied with alternating current at a predetermined frequency, the output from the stator winding of the other of this second pair of machines being fed through an amplifier to the stator winding of one of the first pair of machines, and the stator winding of the other of the first pair of machines providing the alternating current output from the system.

2. An alternating current power generating system incorporating two dynamo-electric machines having stator and rotor windings wound as for a wound rotor induction motor with their rotors mechanically coupled together so as to be rotated simultaneously by the same prime mover, the stator winding of one machine being supplied with alternating current at a predetermined frequency, an alternating current derived from the rotor winding of this machine being fed after amplification, to the rotor winding of the second machine, and the output from the stator winding of the second machine providing the alternating current output from the system.

3. An alternating current power generating system according to Claim 1 or 2 wherein a static inverter provides amplification of the alternating current from the rotor winding of said one machine.

4. An alternating current power generating system according to Claim 1 wherein the first pair of machines are combined to form a single first machine, and the second pair of machines are combined to form a single second machine, the stator winding of the second machine being supplied with said alternating current at a fixed frequency, the output from the rotor winding of this machine being fed via a system of slip-rings and said amplifier to the rotor winding of the first machine, the stator winding of said first machine providing the alternating current output from the system.

5. A modification of the alternating current power generating system according to Claim 1 in which the output of the rotor of said one of the second pair of machines is fed via a system of slip-rings and an amplifier to the stator winding of said one of the first pair of machines, the stator winding of said other of the second pair of machines being connected via a system of slip-rings to the rotor winding of said other of the first pair of machines, and the system includes means for modifying the frequency of the amplified alternating current fed to the stator winding of said one of the first pair of machines.

6. A modification of the alternating current power generating system according to Claim 5 wherein the second pair of machines is replaced by a single machine the rotor shaft of which is coupled to one input of a differential gear box, and the output from the rotor of which is fed via a system of slip-rings and an amplifier to the stator of an electric motor, the shaft of the motor is coupled to a second input of the differential gear box, and the first pair of machines is replaced by a single machine having its rotor coupled to the output of the differential gear box.

7. A modification of the alternating current power generating system according to Claim 4 wherein the stator winding of the second machine is fed with a controllable frequency from an amplifier determined by signals representative of the required turbine load torque and the measured power from the system, such as to provide the required output frequency from the stator winding of the first machine.

8. A modification of the alternating current power generating system according to Claim 7 wherein the two machines are replaced by a single machine, the rotor winding of which is fed with said controllable frequency.

9. A modification of the alternating current power generating system according to Claim 5 in which the one of the second pair of machines having its rotor output fed via said amplifier to the stator winding of one of the first pair of machines is replaced by a phase controller responsive to signals representative of the required load torque and the rotor speed of the first pair of machines, the output from the phase controller being fed via said amplifier to the stator winding of said one of the first pair of machines.

10. A modification of the alternating current power generating system according to Claim 6 wherein the second pair of machines is replaced by a phase controller responsive to signals representative of the required turbine load torque, and the rotor speed of said first machine and the output from the phase controller is fed to the stator of said electric motor.

11. An alternating current power generating system substantially as shown in and as hereinbefore described with reference to any one of Figures 2 to 10 of the accompanying drawings.

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